INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

N00/420/H(2)

CHEMISTRY
HIGHER LEVEL
PAPER 2

Name

Number

Tuesday 7 November 2000 (afternoon)

2 hours 15 minutes

INSTRUCTIONS TO CANDIDATES

- Write your candidate name and number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: Answer all of Section A in the spaces provided.
- Section B: Answer two questions from Section B. You may use the lined pages at the end of this paper or continue your answers in a continuation answer booklet, and indicate the number of booklets used in the box below. Write your name and candidate number on the front cover of the continuation answer booklets, and attach them to this question paper using the tag provided.
- At the end of the examination, indicate the numbers of the Section B questions answered in the boxes below.

QUESTIONS ANSWERED		EXAMINER	TEAM LEADER	IBCA
SECTION A	ALL	/40	/40	/40
SECTION B				
QUESTION	. . . . .	/25	/25	/25
QUESTION	. . . . .	/25	/25	/25
NUMBER OF CONTINUATION BOOKLETS USED	. . . . .	TOTAL /90	TOTAL /90	TOTAL /90

SECTION A

*Candidates must answer **all** questions in the spaces provided.*

In order to receive full credit in Section A, the method used and the steps involved in arriving at your answer must be shown clearly. It is possible to receive partial credit but, without your supporting work, you may receive little credit. For numerical calculations, you are expected to pay proper attention to significant figures.

1. (a) The following table gives information about a number of unknown pure substances labelled A to F. Use this information to answer (i) to (vi).

Substance	Melting point / K	Boiling point / K	Solubility in water
A	14	20	Insoluble
B	953	Decomposes before boiling	Decomposes when added to water to give a solution of pH 7
C	158	188	very soluble; solution has pH 7
D	195	240	very soluble; solution has pH 7
E	922	1380	Insoluble (but reacts with steam)
F	1683	2628	Insoluble

(i) Identify **three** substances that are gases at room temperature and pressure. *[1]*

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(ii) State which **one** of the substances identified in (i) is most likely to be a simple molecular substance with non-polar covalent bonding. *[1]*

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(iii) State the type of bonding that exists **between** molecules of the substance identified in (ii) in its solid state. *[1]*

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(iv) Substance D forms hydrogen bonds both in the liquid and solid state. Name an element (other than hydrogen) which could be present in D which contributes to hydrogen bonding. *[1]*

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(This question continues on the following page)

(Question 1 (a) continued)

(v) Based on melting/boiling point data, which **one** of the substances is most likely to exist as a giant covalent network? Explain your reasoning. *[1]*

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(vi) Of the substances listed, only E conducts electricity in both the solid and liquid states, although F also conducts slightly in these states. What type of substance is *[2]*

E? . . . . . .

F? . . . . . .

(b) With the aid of a diagram in each case, explain the following:

(i) ethanoic acid has a relative molecular mass, M_r, of 120 in benzene, but has a M_r of only 60 in aqueous solution. *[2]*

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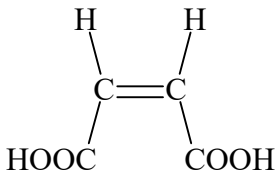
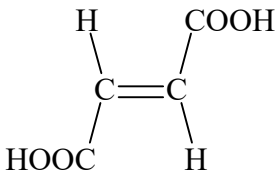
(ii) cis-butenedioic acid has a lower melting point than its trans-isomer: *[2]*



cis isomer



trans isomer

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(Question 1 (b) continued)

(iii) ethanol has a boiling point of 78 °C whereas its isomer CH_3OCH_3 has a boiling point of –25 °C. *[2]*

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2. This question concerns the atomic structure of iron.

(a) (i) Show the electron configurations (indicating electron spins) of iron and its positive ions, by filling in the boxes below: *[3]*

	4s	3d				
Fe^0:						
Fe^{2+}:						
Fe^{3+}:						

(ii) What is the oxidation state of iron in $[Fe(CN)_6]^{4-}$? *[1]*

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(iii) Iron can also exist in an oxidation state of +6. Give the formula of a species containing only iron and oxygen in which Fe(VI) might exist. *[1]*

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(b) (i) Define the term *ligand*. *[1]*

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(ii) In terms of acid–base theories, what type of a reaction is the formation of $[Fe(H_2O)_6]^{2+}$ from Fe^{2+} and water? Explain your answer. *[2]*

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(iii) Explain why the two iron complex ions $[Fe(H_2O)_6]^{2+}$ and $[Fe(CN)_6]^{4-}$ are different colours. *[2]*

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3. Dinitrogen oxide decomposes to give nitrogen and oxygen according to the following equation:

$$2N_2O(g) \rightarrow 2N_2(g) + O_2(g) \qquad \Delta H^{\ominus} = -82 \text{ kJ mol}^{-1}$$

(a) The decomposition is a first order reaction in the presence of gold as a catalyst. The half-life of the catalysed reaction at 834 °C is 1.62×10^4 s.

(i) Calculate the rate constant (velocity constant), *k*, for the reaction at this temperature and give the units of *k*. *[1]*

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(ii) Calculate the activation energy of the reaction at this temperature, given the Arrhenius constant, $A = 25 s^{-1}$. *[2]*

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(iii) The decomposition of dinitrogen oxide without a catalyst is bimolecular. Suggest a possible mechanism for the reaction indicating the equation for each step: *[2]*

Slow step: . . . . . .

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Fast step: . . . . . .

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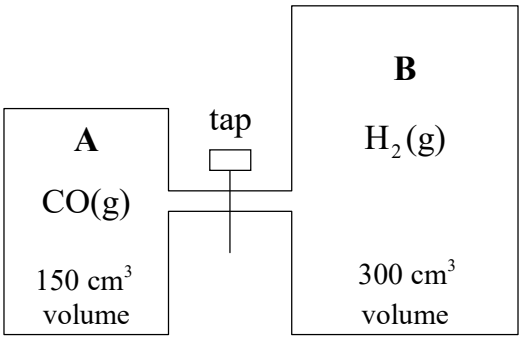
(b) Draw a labelled diagram showing the potential energy changes during the catalysed and uncatalysed reaction given above. *[2]*

4. Methanol is an important industrial solvent and fuel. It can be produced from carbon monoxide and hydrogen according to the following equation:

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91 \text{ kJ mol}^{-1}$$

The effect of different catalysts on this reaction is investigated using the following apparatus:



A contains 1 mole of carbon monoxide and **B** contains 2 moles of hydrogen. The gases in both containers are at the same temperature and pressure. The tap is closed at the start of the experiment.

(a) What pressure change will occur, if any, in the containers when the tap is opened

(i) and the gases are allowed to mix (but before they start to react)? *[1]*

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(ii) as the reaction takes place? *[1]*

. . . . . .

(b) (i) What will happen to the temperature as the gases begin to react? *[1]*

. . . . . .

(ii) What will happen to the concentration of methanol if the system is allowed to reach equilibrium at a lower temperature? *[1]*

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(This question continues on the following page)

(Question 4 continued)

(c) (i) Write the equilibrium expression for the above reaction, and give the units for K_c. *[1]*

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(ii) Calculate a value for K_c if the maximum yield of methanol is 85 %. *[3]*

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(iii) When this reaction is carried out on an industrial scale, the yield is about 60 %. Suggest a reason for this. *[1]*

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(iv) Copper is a good catalyst for this reaction. What effect, if any, will the addition of copper have on the value of K_c? *[1]*

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SECTION B

*Answer **two** questions. You may use the lined pages at the end of this paper or continue your answers in a continuation answer booklet. Write your name and candidate number on the front cover of the continuation answer booklets, and attach them to this question paper using the tag provided.*

5. (a) The first ionisation energies of the elements Na to Ar are given in Table 7 of the Data Booklet.

(i) Account for the **general** increase in ionisation energy across the period. *[2]*

(ii) Explain why the first ionisation energy of aluminium is less than that of magnesium. *[2]*

(iii) Explain why the first ionisation energy of sulfur is less than that of phosphorus. *[2]*

(b) List the formulas of the chlorides of Na, Mg, Al, Si and P. Why is there no chloride of argon? Give the name of the bonding in the chloride of silicon both within and between molecules. *[5]*

(c) Classify the acid–base character of **one** oxide of **each** of the elements in the period from Na to S. Illustrate your answer by writing balanced chemical equations for the reaction of magnesium oxide and of a phosphorus oxide with water. Explain why 'pure' rain water is slightly acidic (pH 5.7). *[6]*

(d) (i) Write balanced equations to show how aluminium oxide reacts with hydrochloric acid and with sodium hydroxide. *[2]*

(ii) Write a balanced equation to show what happens when $FeCl_3$ is added to water. *[1]*

(e) Describe and explain the redox reactions of Cl_2, Br_2 and I_2 with Cl^-, Br^- and I^- ions. *[5]*

6. When solid blue copper(II) sulfate pentahydrate, $CuSO_4 \cdot 5H_2O$, loses water the white solid, copper(II) sulfate monohydrate, $CuSO_4 \cdot H_2O$, is produced as represented by the following equation:

$$CuSO_4 \cdot 5H_2O(s) \rightleftharpoons CuSO_4 \cdot H_2O(s) + 4H_2O(g)$$

The thermodynamic data for the substances involved in the reversible process are:

	$\Delta H_f^{\ominus}$ / kJ mol^{-1}	$S^{\ominus}$ / J K^{-1} mol^{-1}
$CuSO_4 \cdot 5H_2O(s)$	–2278	305
$CuSO_4 \cdot H_2O(s)$	–1084	150
$H_2O(g)$	–242	189

(a) (i) Name and define the terms $\Delta H_f^{\ominus}$ and $S^{\ominus}$ and explain the symbol '$\ominus$'. *[5]*

(ii) Explain why, in the case of $S^{\ominus}$, the symbol 'Δ' is not included. *[1]*

(iii) What is the $\Delta H_f^{\ominus}$ value of elemental copper? *[1]*

(b) (i) Calculate the value of $\Delta H^{\ominus}$ for the above reaction and state what information the sign of $\Delta H^{\ominus}$ provides about this reaction. *[4]*

(ii) Calculate $\Delta S^{\ominus}$ for the reaction and state the meaning of the sign of $\Delta S^{\ominus}$ obtained. *[4]*

(iii) Identify a thermodynamic function that can be used to predict reaction spontaneity and state its units. *[2]*

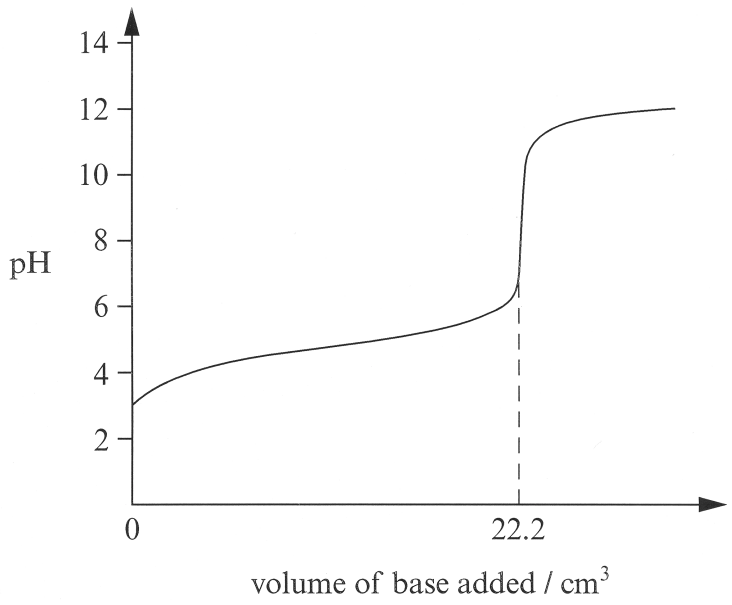
(c) (i) Use the values obtained in (b) above to determine if the following reaction is spontaneous or non-spontaneous at 25 °C:

$$CuSO_4 \cdot 5H_2O(s) \rightleftharpoons CuSO_4 \cdot H_2O(s) + 4H_2O(g)$$

Identify which compound $CuSO_4 \cdot 5H_2O(s)$ or $CuSO_4 \cdot H_2O(s)$ is more stable at 25 °C. *[5]*

(ii) Use the values obtained in (b) to determine the Centigrade temperature above which the other compound in (c) (i) is more stable. *[3]*

7. (a) The titration of 25.0 cm^3 of 0.100 $mol\,dm^{-3}$ monoprotic acid HA with a base MOH gives the following graph:



(i) State whether the acid and base used are weak or strong. Explain your answer. *[4]*

(ii) Use the above data to determine the concentration of the base and give its units. *[2]*

(iii) Using HIn as an example, explain qualitatively how an acid–base indicator works. *[3]*

(iv) Write the equilibrium expression for HIn and show how the pK_a value of the indicator relates to the pH value at which it changes colour. *[3]*

(v) State the pK_a value of an indicator that will be most suitable for use in the above titration. *[1]*

(b) Explain why an aqueous sodium ethanoate solution is basic whereas an aqueous ammonium ethanoate solution is approximately neutral. *[4]*

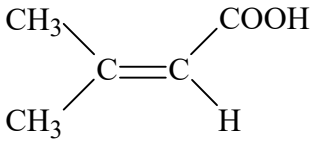
(c) If the pH of water in a swimming pool goes above 8, aluminium sulfate, $Al_2(SO_4)_3$, is added to it to adjust its pH. With the help of formulas and acid–base properties of the ions present, explain how this is achieved. *[3]*

(d) A household cleaner contains aqueous ammonia. A 2.447 g sample of the cleaner is diluted with water to 20.00 cm^3. This solution requires 28.51 cm^3 of 0.4040 $mol\,dm^{-3}$ sulfuric acid to reach the equivalence point.

(i) Write a balanced chemical equation for the reaction of sulfuric acid with ammonia to form ammonium sulfate. *[1]*

(ii) Calculate the amount (moles) of sulfuric acid required for this reaction, and the amount (moles), mass and percentage by mass of ammonia present in the household cleaner. *[4]*

8. Molecule **A** contains two important functional groups and has the structural formula:

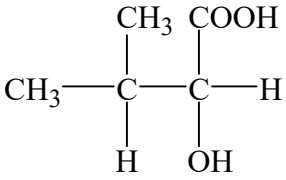


(a) For each functional group present in **A**, give **one** chemical reaction that could be carried out and the result that would indicate the presence of the group. *[4]*

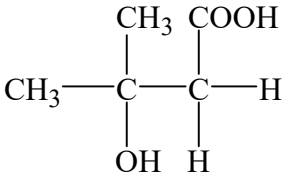
(b) (i) With the help of Table 18 in the Data Booklet, identify **three** characteristic infrared absorption ranges corresponding to specific bonds for compound **A**. *[2]*

(ii) With the help of Table 19 in the Data Booklet, identify **three** characteristic ^{1}H NMR chemical shift values for **A**. State the ratio of the areas of the peaks obtained for compound **A**. *[3]*

(c) When compound **A** reacts with water in the presence of an acid catalyst, products **B** and **C** can be obtained.



Compound **B**



Compound **C**

(i) Which of the two techniques IR or NMR spectroscopy would be more useful in determining whether the product is **B** or **C**? Explain your answer. *[3]*

(ii) How could **B** and **C** be distinguished by means of a chemical reaction? State the basis of the reaction, the reagent you would use, and the results expected for both **B** and **C**. *[4]*

(d) (i) Explain what is meant by *optical activity*. Describe the structural characteristic of an optically active molecule. *[2]*

(ii) Identify which compound, **B** or **C**, can show optical activity. Draw structures of the two enantiomers to illustrate clearly the relationship between them. How do the two enantiomers differ in their optical activity? *[4]*

(e) Both **B** and **C** contain two hydroxyl groups, but only one of these groups is acidic. Give **two** reasons why that is the case. *[3]*